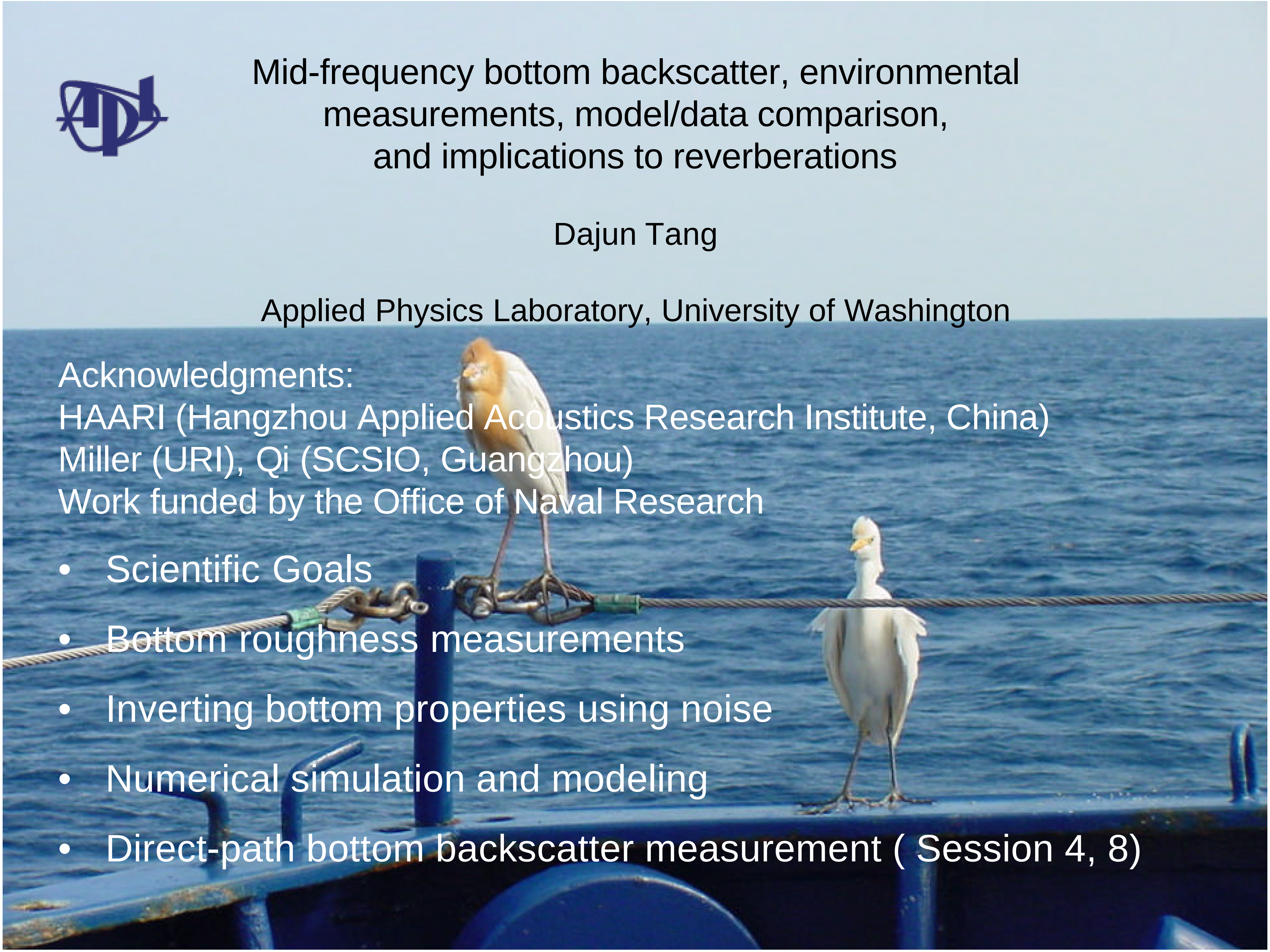

Mid-frequency bottom backscatter, environmental measurements, model/data comparison, and implications to reverberations

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- Scientific Goals
- Bottom roughness measurements
- Inverting bottom properties using noise
- Numerical simulation and modeling
- Direct-path bottom backscatter measurement (Session 4, 8)

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Scientific Goals

<u>Hypothesis:</u>

Bottom roughness is the main scattering mechanism in the mid-frequency (3-4 kHz) range at the ECS site.

Although backscatter measurements are many, there is a lack of data on bottom characterization which prevents direct model/data comparison.

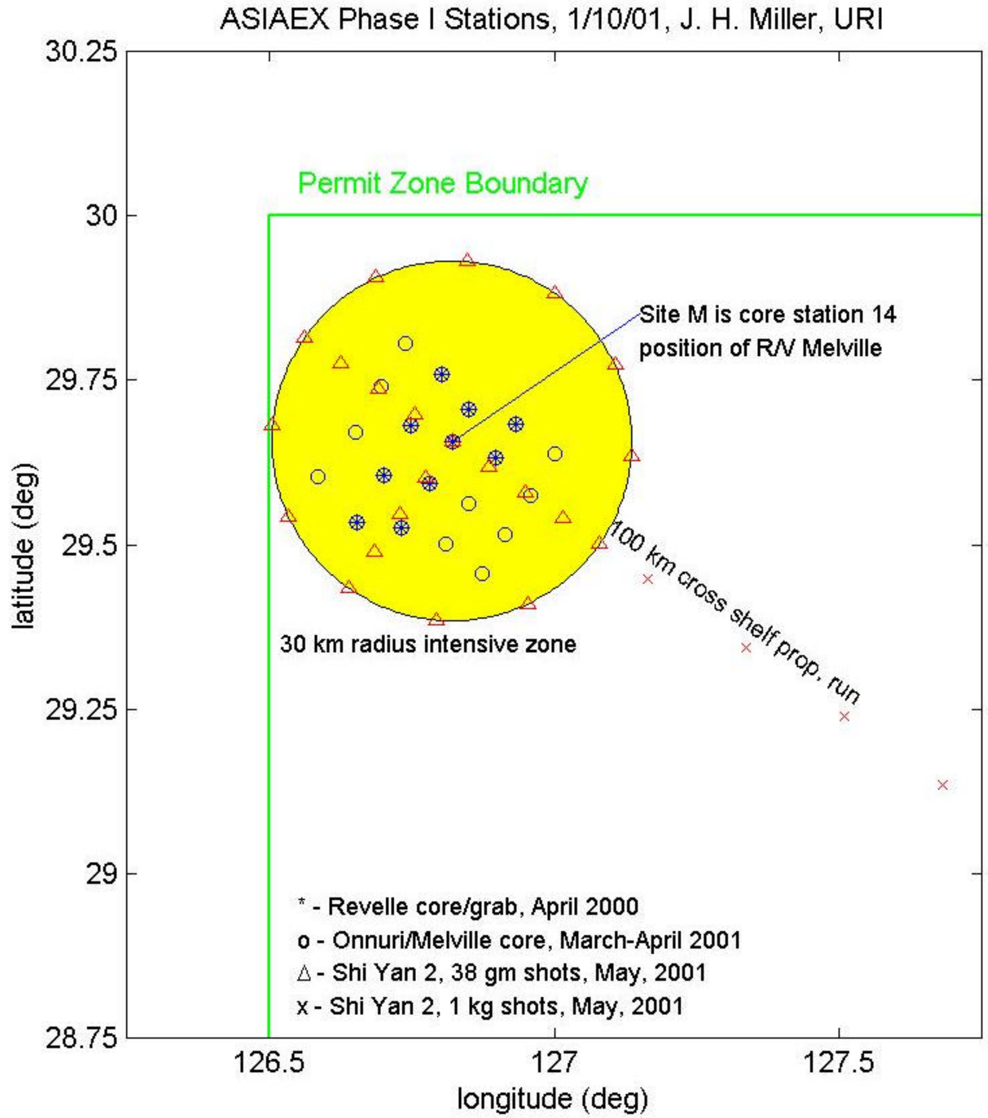
<u>Goal:</u>

Model/data comparison with model parameters measured at required resolutions.

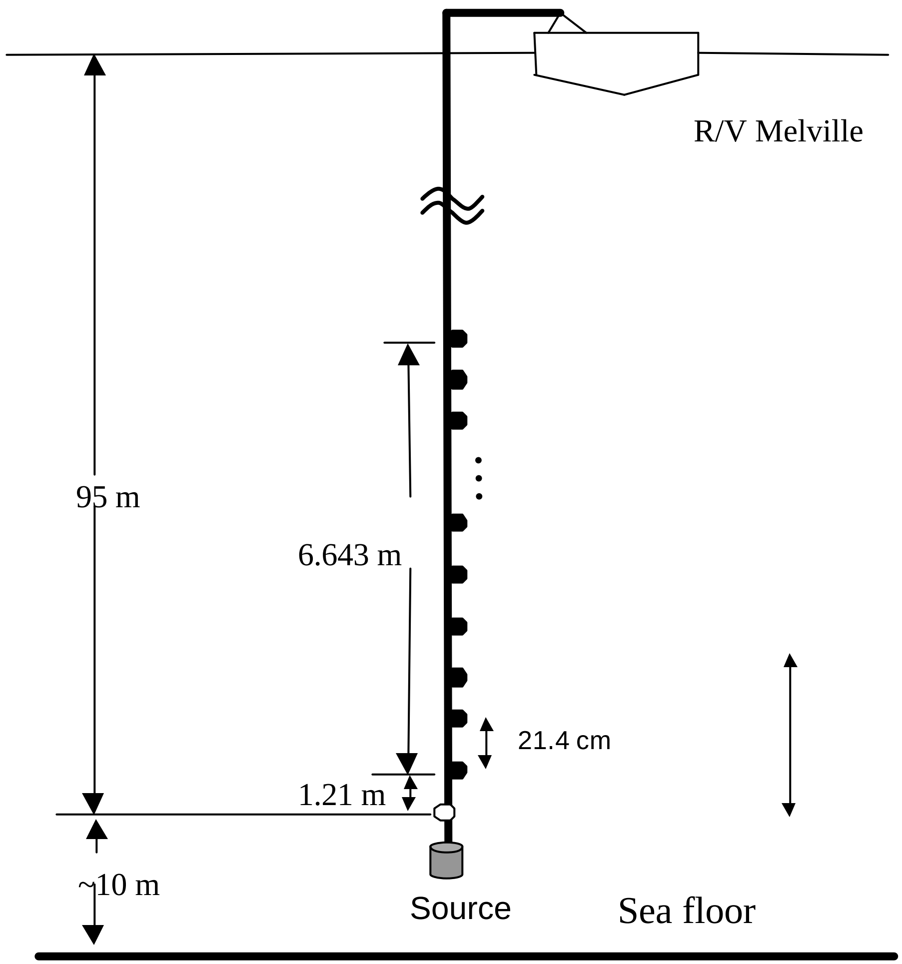
Approach

- Using ambient noise to estimate C, ρ, and α at the same frequency range with cores as supporting data sets
- Using IMP2 to measure bottom roughness at the required spatial resolution
- Time-domain simulation of bottom backscatter using 1^{st} order perturbation theory. All simulation parameters are the same as those in real experiments
- HAARI vertical array system to measure bottom scatter

Background Information



Source and 32 Element Array



Approach

- **Using ambient noise to estimate C, r, and a at the same frequency range with cores as supporting data sets**

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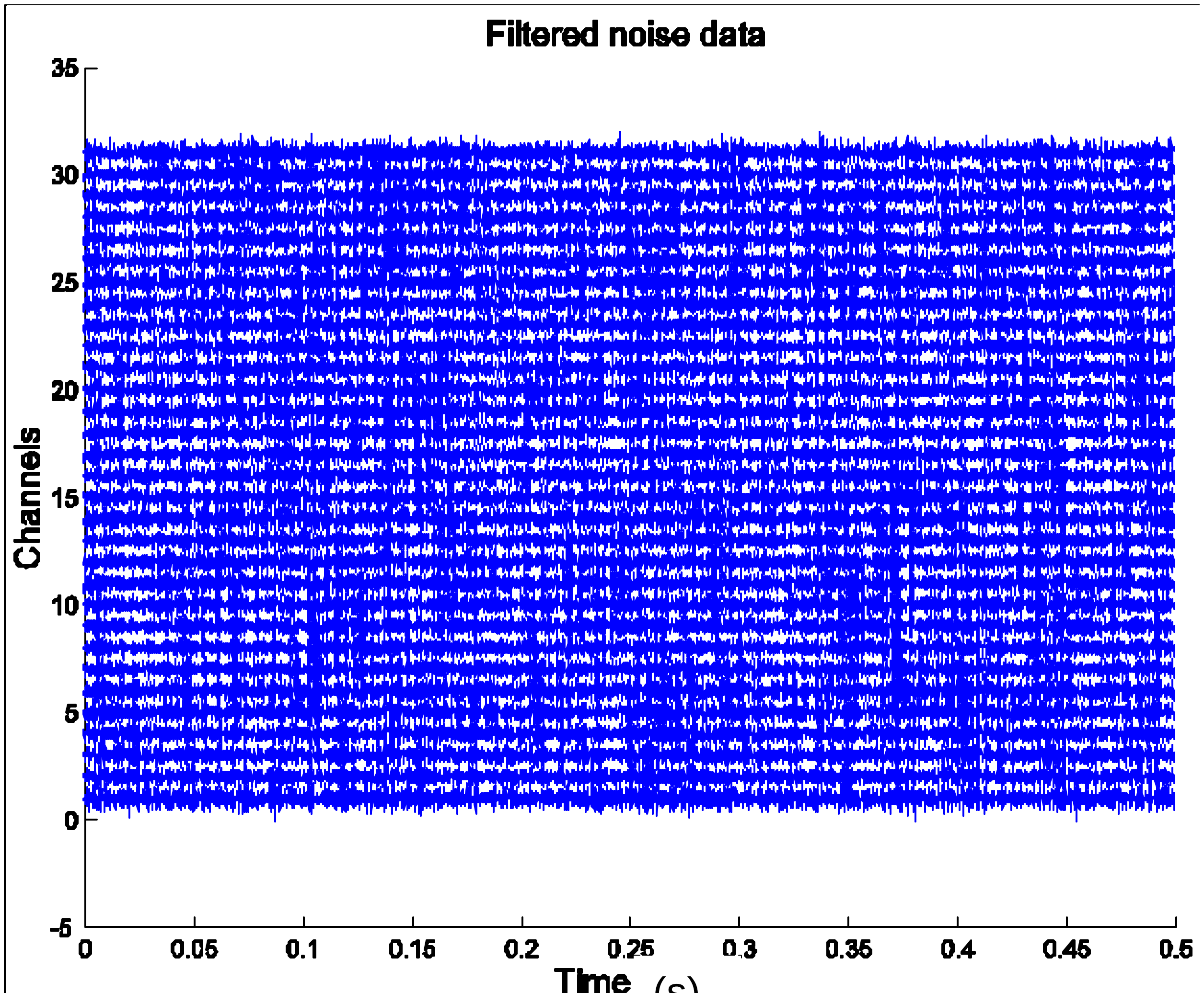
Using noise to measure bottom reflection loss $|R(f,\theta)|^2$



Bottom parameters estimated: C, ρ, α

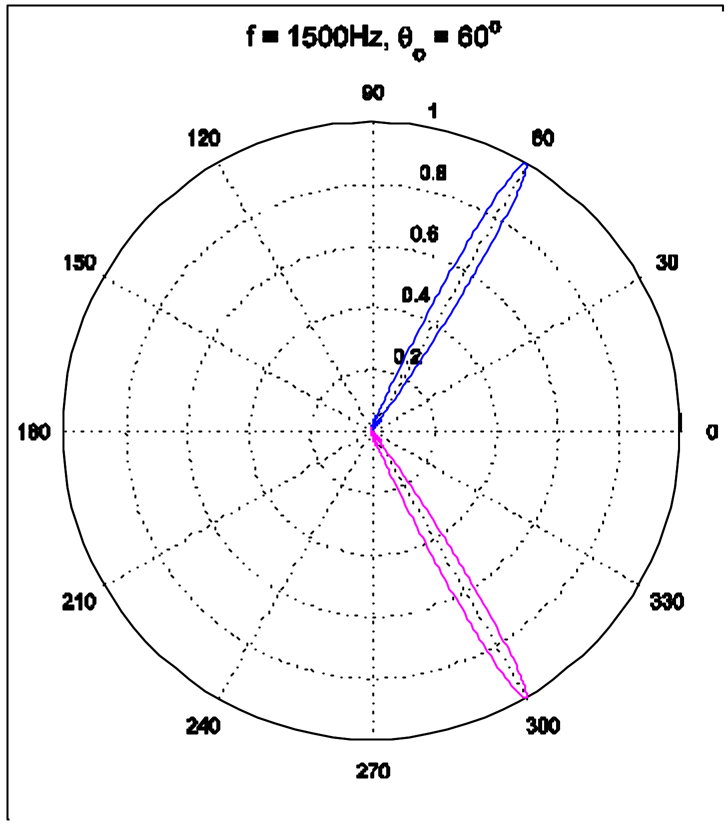
Assumption: Surface and bottom scatter is small.

Advantage of using ambient noise:

- Need only a single station.
- Passive.
- Provides data over wide frequency band.
- With a moving vertical array, provides potential for large area survey.
- Needs no knowledge of the noise sources.
- Has potential to be applied to range-dependent environments since the array is sensitive only to local modes.

Dominant Noise Sources

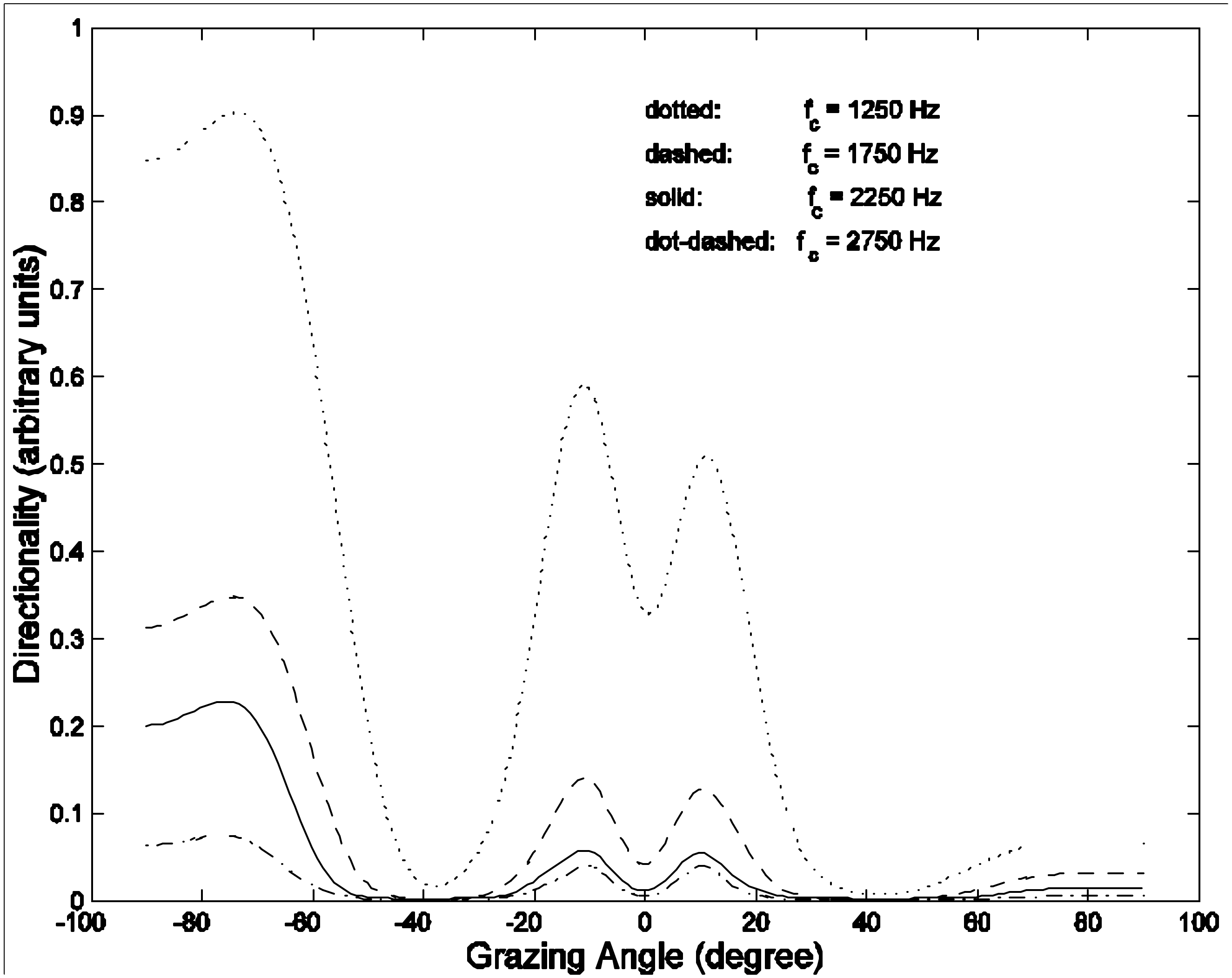
Beam-forming to find incident and reflected energy



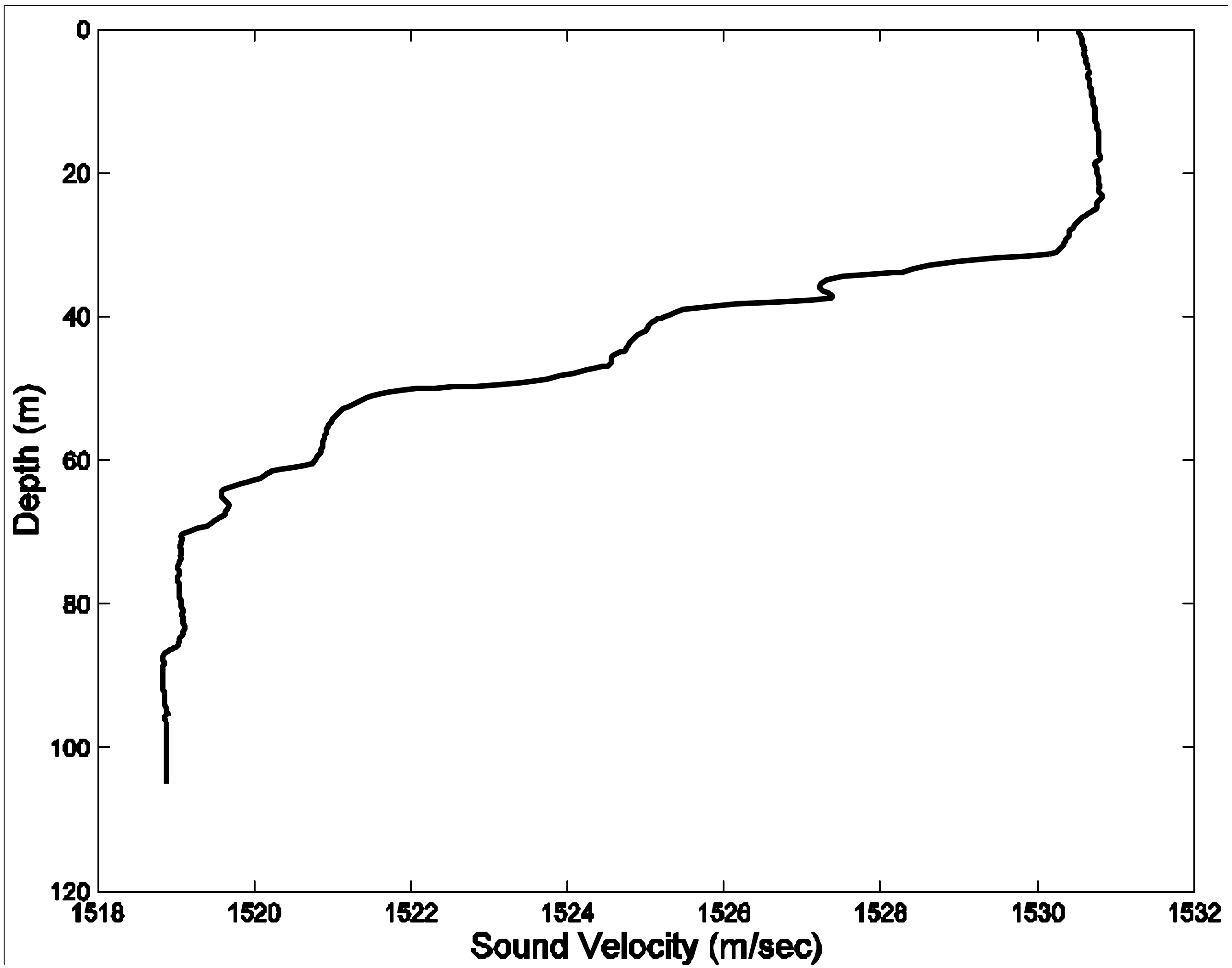
For an infinitely-long array, $|R(\theta,f)|^2$ is the ratio of the beams.

- Pt. 9 by Furduyev from AKUSTIKA OKEANA in Russian, Ed. Brekhovskikh.
- Harrison, C. in SACLANTCEN uncertainties workshop, 2002
- Tang, D. in SACLANTCEN uncertainties workshop, 2002

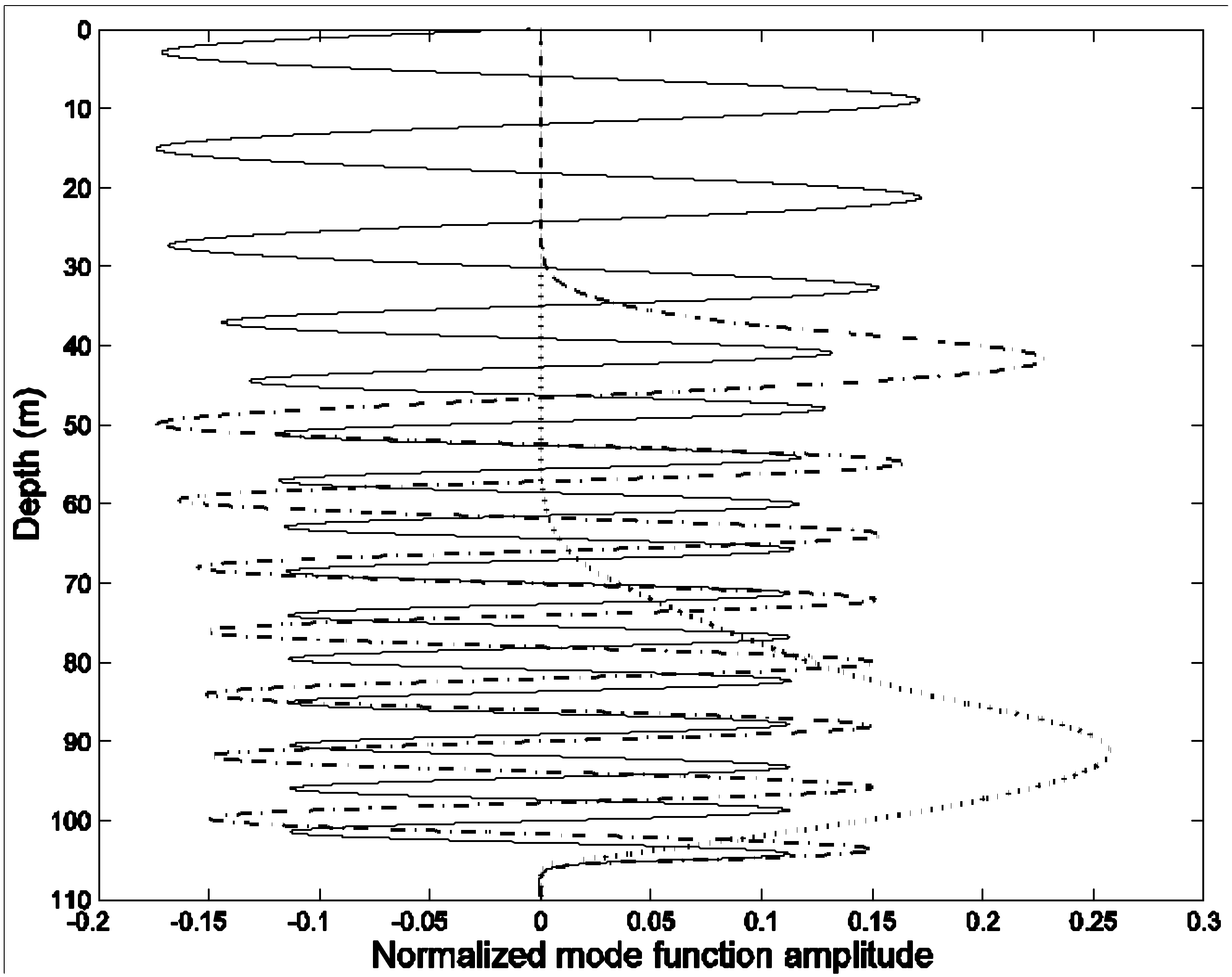
Beams in 500 Hz bands, averaged over 60 half-seconds segments



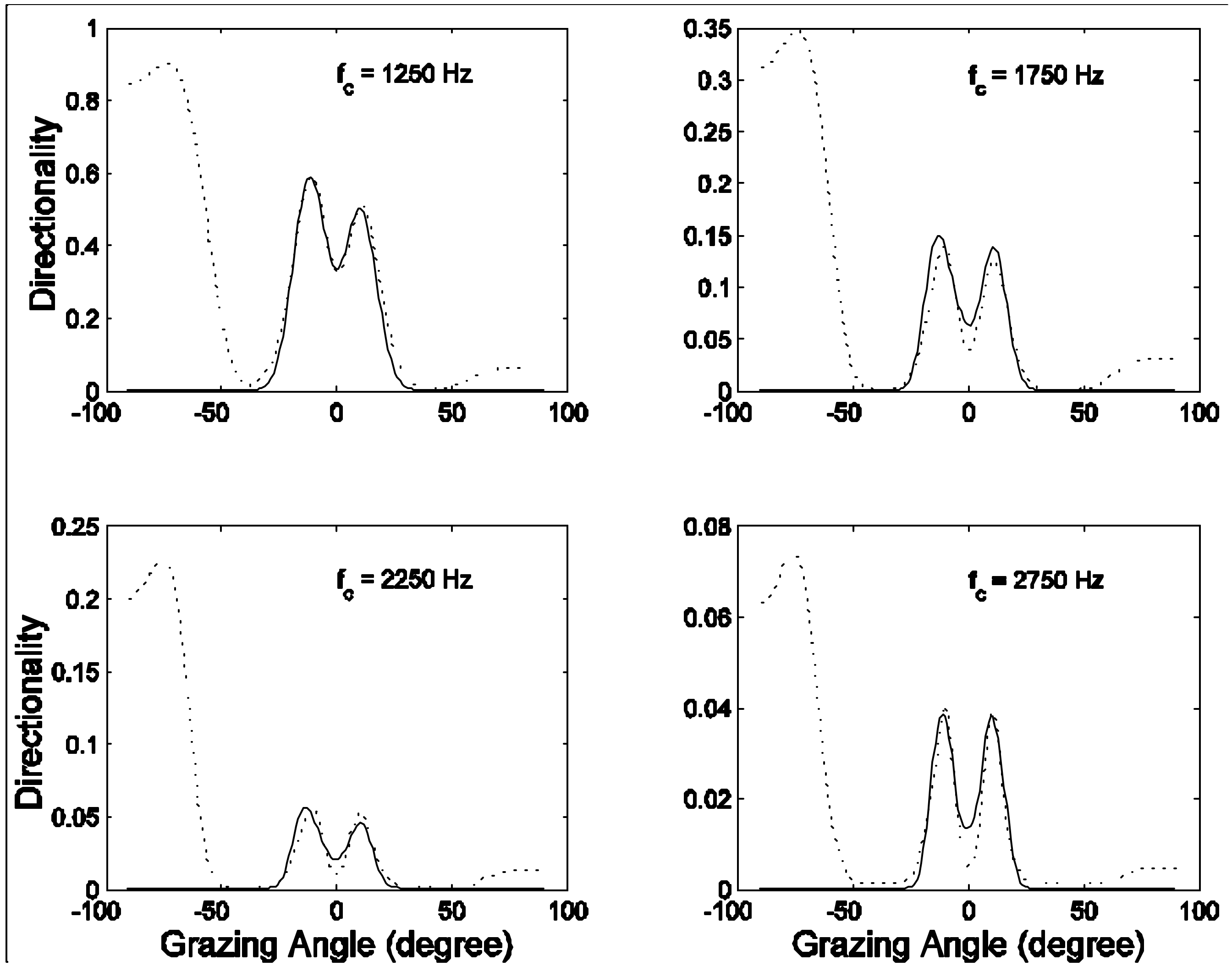
Typical Sound Speed Profile at the ECS site

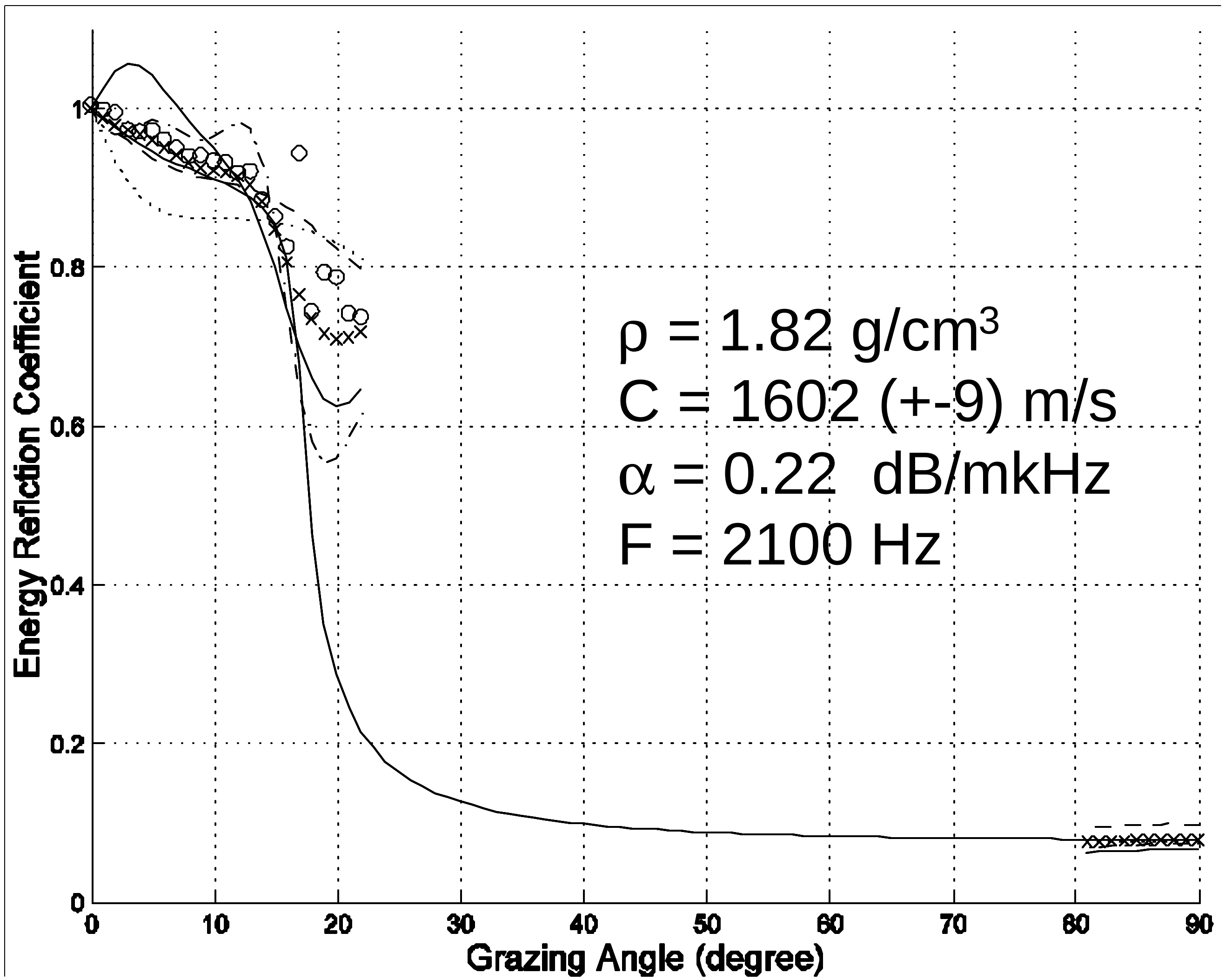


Mode Amplitudes



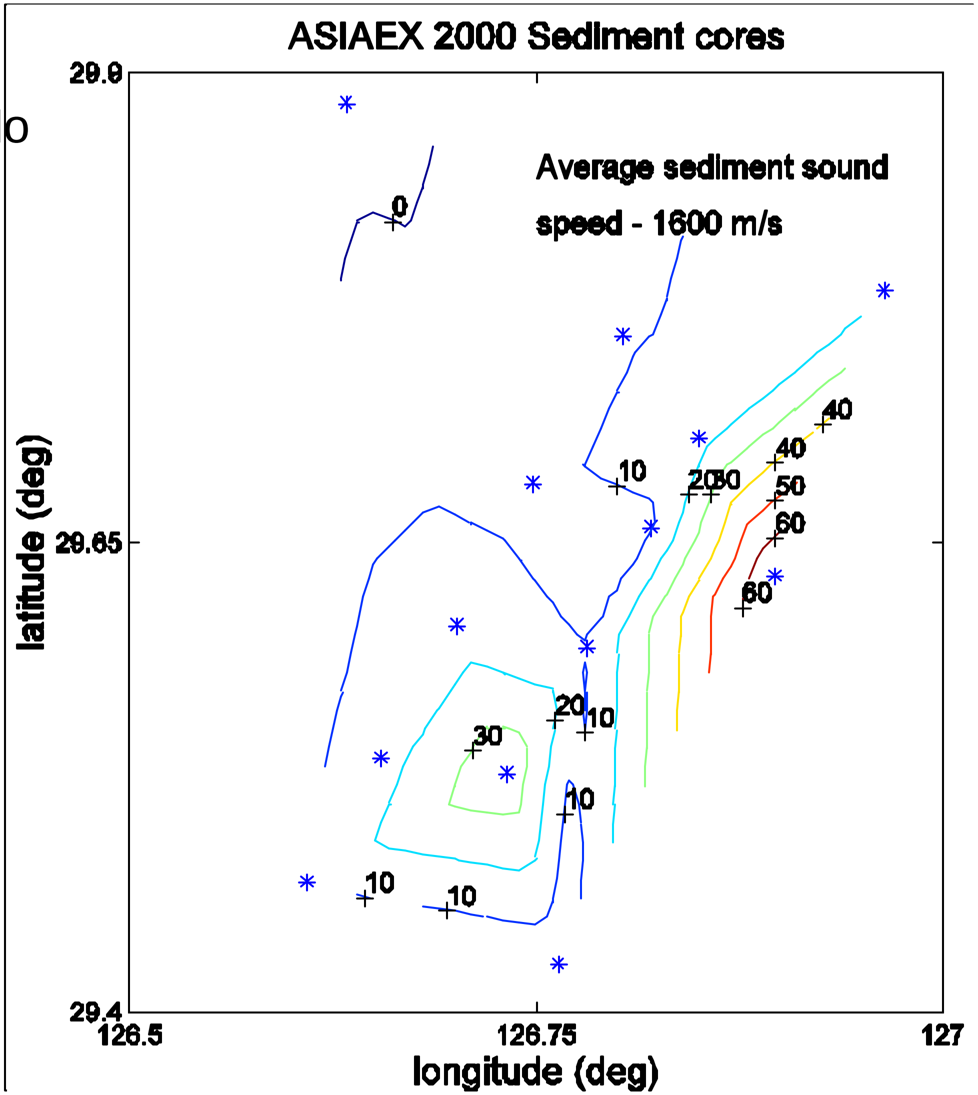
Model/data comparison, 500 Hz bands, 100 realizations using Kraken





ρ = 1.82 g/cm3
C = 1602 (+-9) m/s
α = 0.22 dB/mkHz
F = 2100 Hz
Energy Reflction Coefficient
Grazing Angle (degree)
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50
60
70
80
90

ρ = 1.87 - 1.92 g/cm^3. No attenuation data from cores. (Miller, URI and Qi of SCSIO)



Summary on noise inversion:

Sound speed, density, and attenuation coefficient are obtained via $|R|^2$ from ambient and ship's self noise.

Sound speed results are consistent with core results.

Density results are slightly lower than core results (loss of surficial water in cores?).

No direct measurements of attenuation coefficient.

Overall inversion results are encouraging and basic-research level experiments are needed.

Because all sonar performance in shallow waters depends on surficial bottom geo-acoustics parameters, using ambient noise to invert these parameters is a powerful, fruitful, and convenient method

Approach

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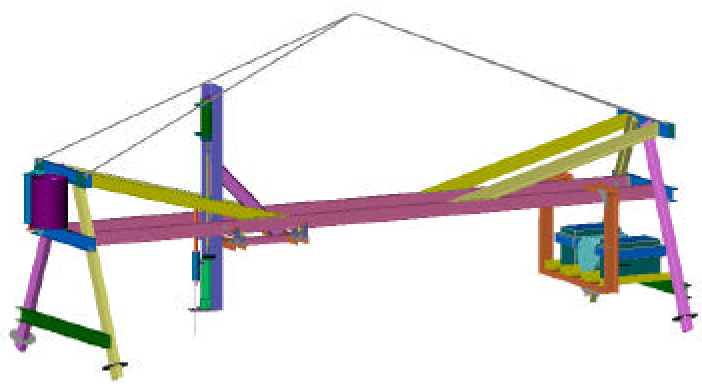
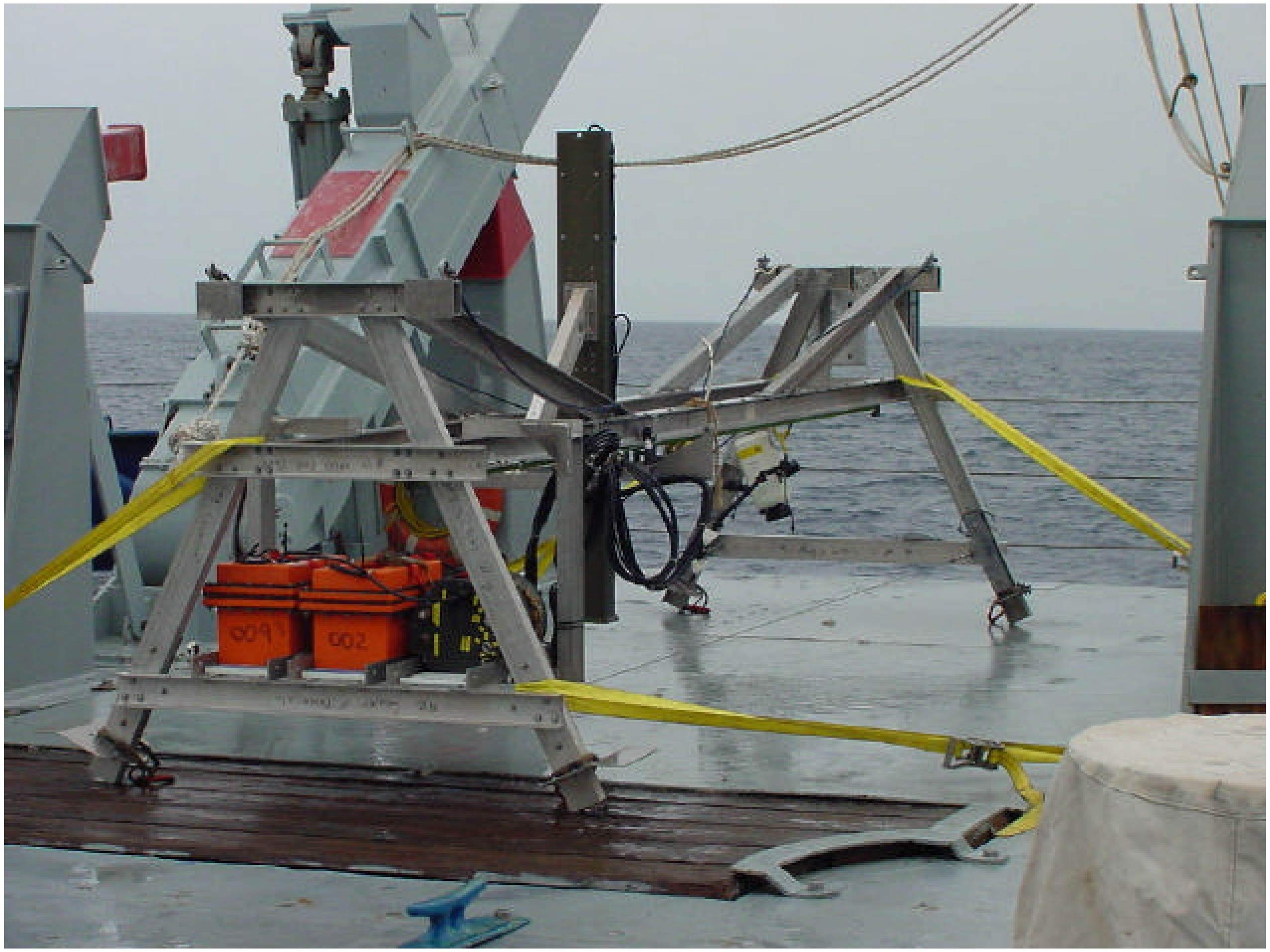
- HAARI vertical array system to measure bottom scatter

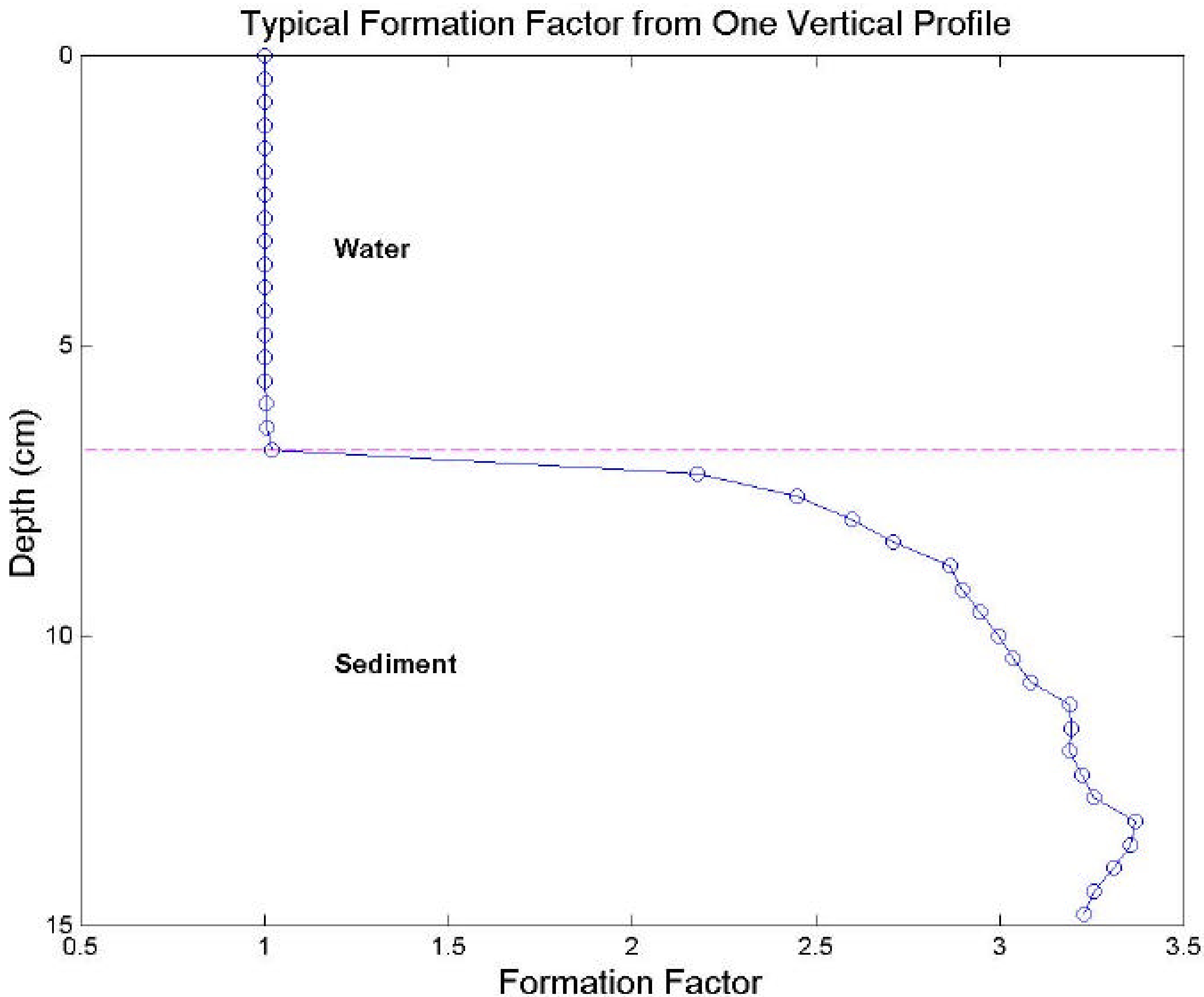
Conductivity System

The IMP2 (2nd generation In situ Measurement of Porosity) is designed to measure seafloor roughness and sub-bottom heterogeneity with centimeter-scale resolution ---- necessary to model backscatter at 3-4 kHz.

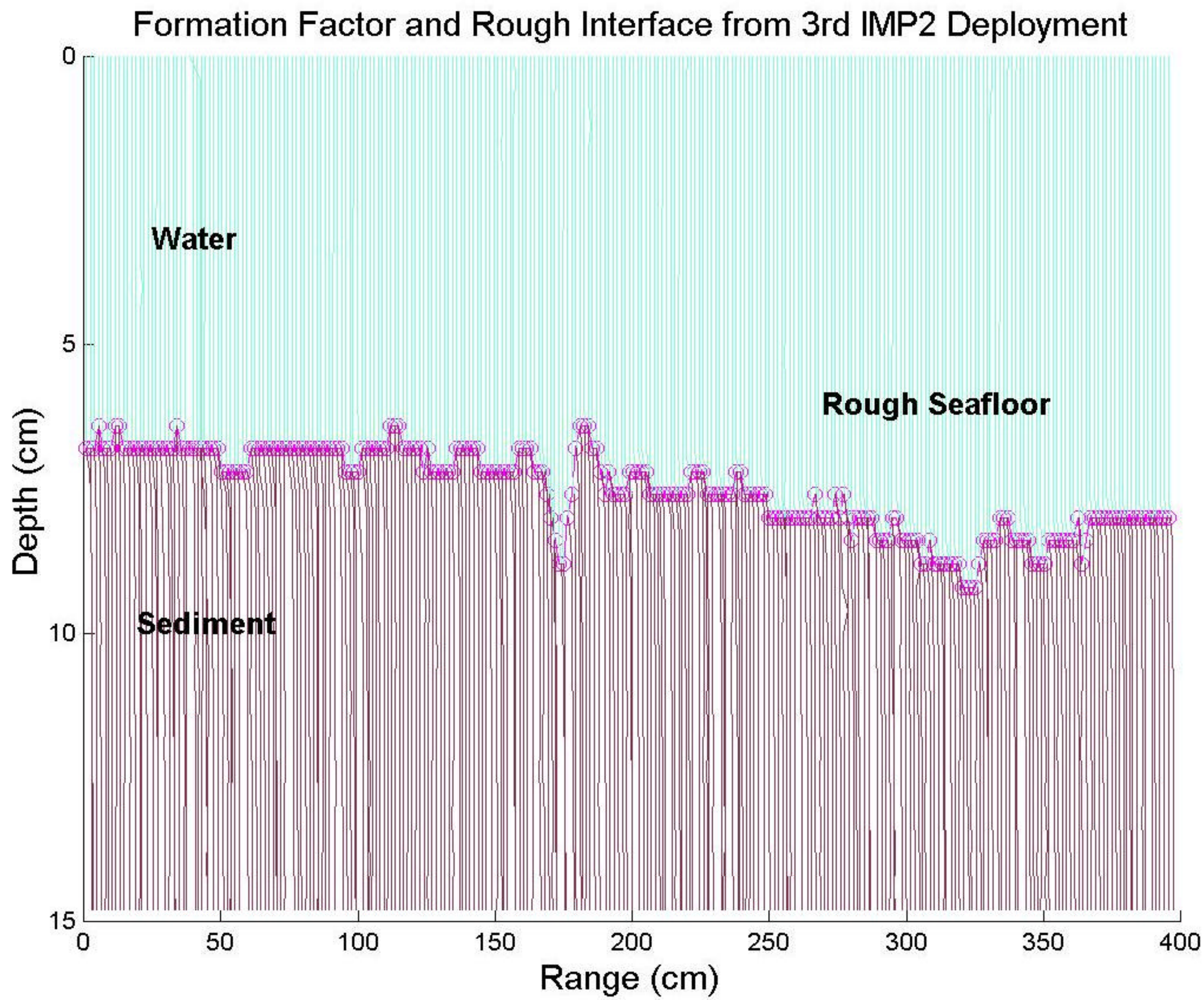


IMP2 on the Melville at the ECS site





Typical Formation Factor from One Vertical Profile
Water
Sediment
Depth (cm)
Formation Factor
0
5
10
15
0.5
1
1.5
2
2.5
3
3.5

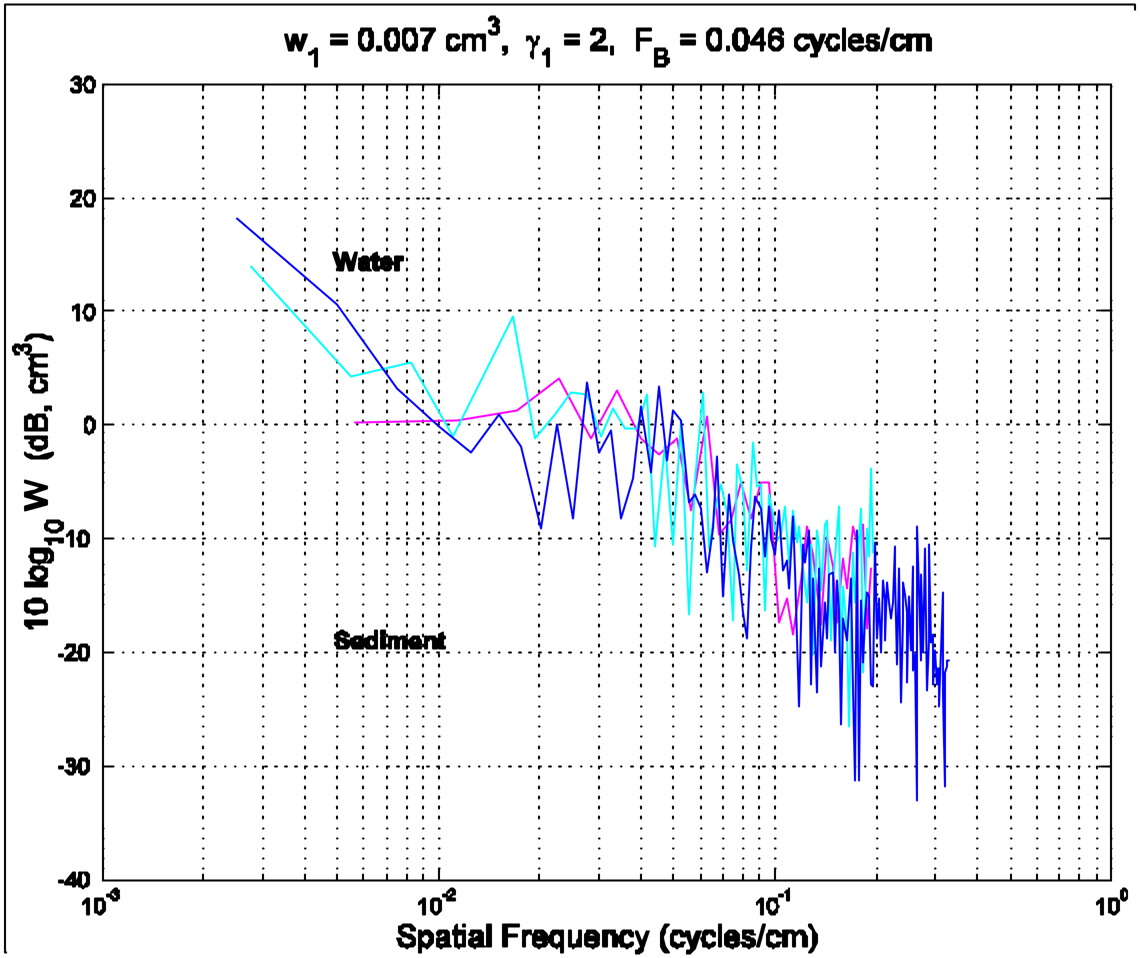


Formation Factor and Rough Interface from 3rd IMP2 Deployment
Water
Rough Seafloor
Sediment
Depth (cm)
Range (cm)
0
5
10
15
0
50
100
150
200
250
300
350
400

Video picture of ECS seafloor, 2nd deployment

Video picture of ECS seafloor, 3rd deployment

Estimated spectrum from ECS data. It will be an input to model backscatter



$$S1(k) = w_1/k^{\gamma_1}$$

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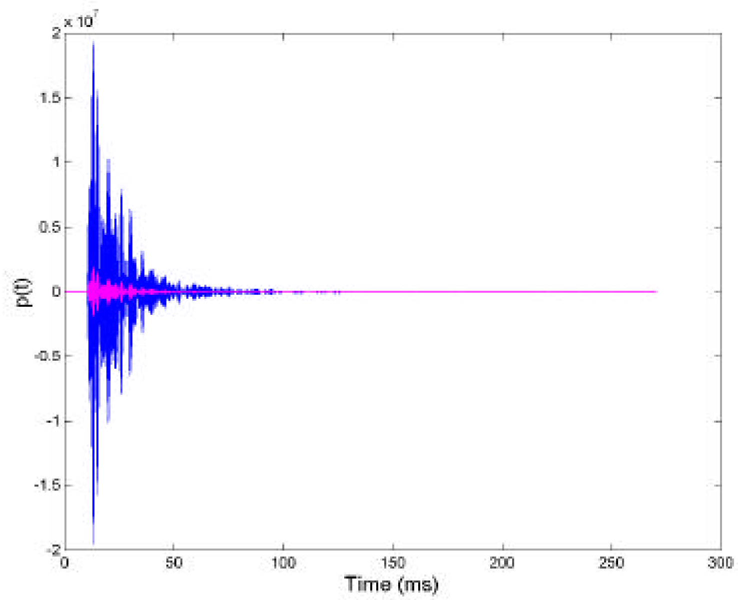
Direct-path backscatter model

$$p(t) = s''(t) * I(t)$$

$$I(t) = \frac{1}{4pc^2} \iint dxdy \frac{t(x,y)}{R_i R_s} z(x,y) d(t - t_d)$$



Approach

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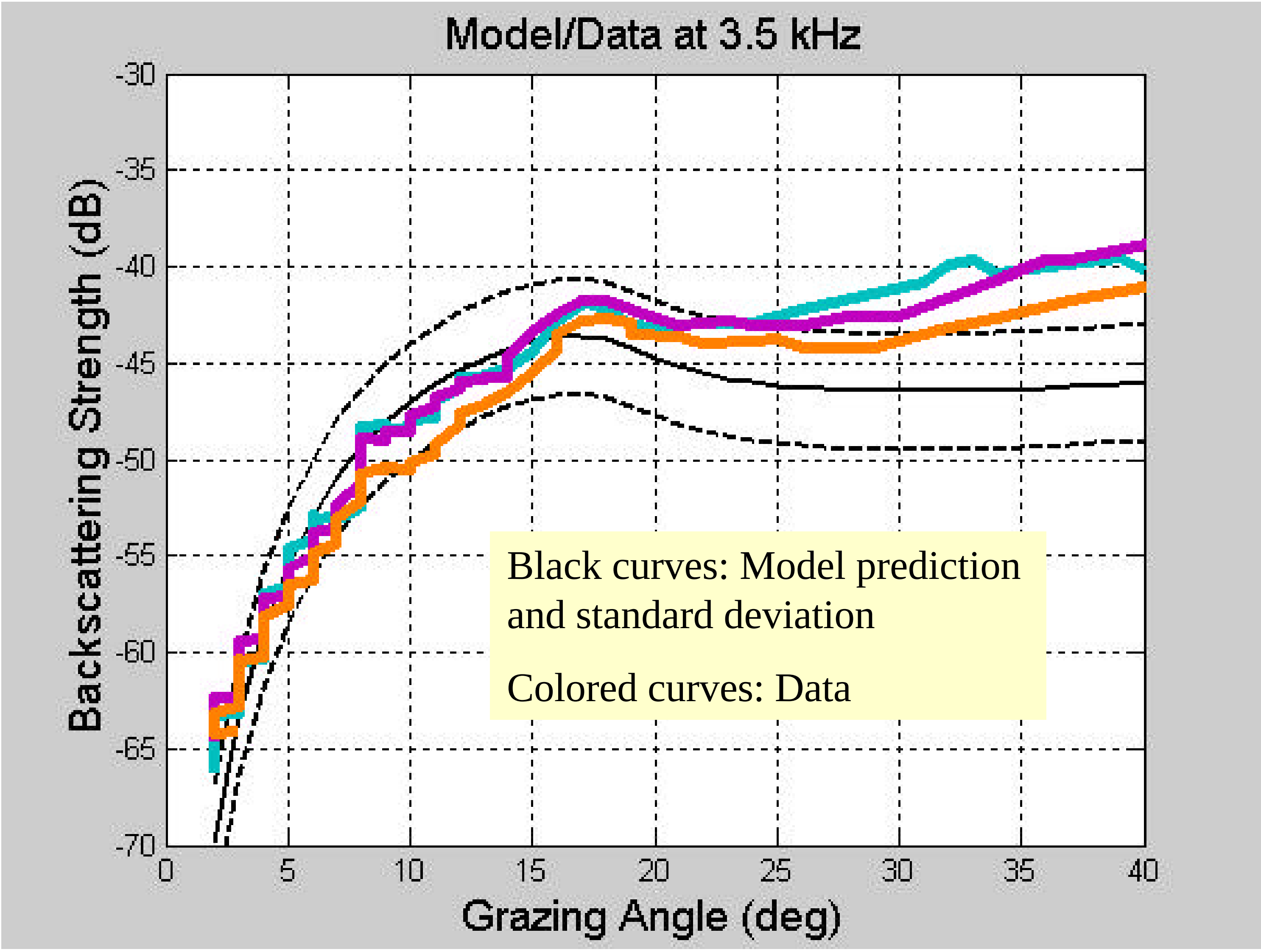
- Time-domain simulation of bottom backscatter using 1st order perturbation theory. All simulation parameters are the same as those in real experiments
- **HAARI vertical array system to measure bottom scatter (Wang, session 4, 8)**


Model/Data at 3.5 kHz
Backscattering Strength (dB)
-30
-35
-40
-45
-50
-55
-60
-65
-70
0
5
10
15
20
25
30
35
40
Grazing Angle (deg)
Black curves: Model prediction and standard deviation
Colored curves: Data

Summary and Discussions:

With contemporaneous measurements of acoustics and environmental data at the same location, model/data comparison indicates that bottom backscatter in the frequency band of 3-4 kHz is dominated by bottom roughness .

Mode of operation:

- Scientific hypotheses to be tested
- Simulation of experiment results with realistic models
- Measure parameters which are required inputs to models
- Experiment data analysis – confirmation of the starting hypotheses and refining of understanding

A (debatable) Statement

It is the environment, s…..

It is the acousticians, not geologists, who should take a lead on measuring bottom geo-acoustic parameters for underwater acoustics applications.

It is all in the environment, …..

High quality measurement of
bottom geo-acoustic parameters
is key to understanding shallow water acoustics

Data will be available to all interested ASIAEX scientists

Caution should be taken when extrapolate mid-frequency environmental data to low-frequency applications

Related topics:

Reverberation simulation in the time domain – surface and bottom roughness scatter

Transport theory of long-range reverberation

Estimating reflection loss from broadband reverberation data – speculative